

The accompanying sketch shows the section of country traversed by the tornado. (See fig. 1.)

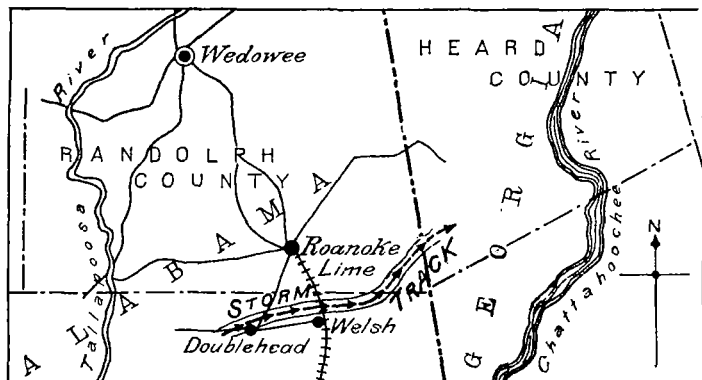


FIG. 1.—Track of tornado in eastern Alabama, March 20, 1905.

## STUDIES ON THE DIURNAL PERIODS IN THE LOWER STRATA OF THE ATMOSPHERE.

### II.—THE DIURNAL PERIODS OF THE BAROMETRIC PRESSURE.

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#### THE STATUS OF THE PROBLEM OF DIURNAL PRESSURE.

The physical relations between the waves of temperature and pressure in the lower strata of the atmosphere, together with their influence upon the electrical and the magnetical fields in the air, have formed subjects of constant investigation during the past forty years, but, unfortunately, without any satisfactory results. In my *International Cloud Report*, Weather Bureau, 1898, chapter 9, some account of the problem was given, and an attempt was made to throw some additional light upon the subject. The principal point brought out was the fact that there is a very close connection between the variation of the pressure and the magnetic fields over the earth, although I was unable to show what the physical process is which unites them. The papers of this series are supplementary to that investigation, and they show that two important elements have been lacking in the terms of the problem; namely, the variation of the temperature with the height, and the existence of streams of ions or free charges of electricity in the lower atmosphere. Without them it was not possible to explain the connection between the several types of observed phenomena.

There have been in general two lines of attack upon the problem of the coexistence of the single, the double, and the triple barometric waves, as determined by the harmonic components: First, that they are due directly to an effect of the temperature upon the pressure by a change in the density of the lower strata of air; and second, that a dynamic-forced wave is generated chiefly by solar radiation acting in the upper strata of the atmosphere. However, it has not been possible to associate the surface-temperature wave with the semidiurnal and the tri-diurnal waves of pressure, because it has been assumed that the surface-temperature wave extends with the same periodic phase into the lower strata. We have shown in the preceding paper that this is not the case, and that there is now sufficient reason for reopening the problem at this place. Regarding the solution by a dynamic-forced wave, it has become more evident<sup>1</sup> from the studies of the absorption of the solar radiation, by means of the bolometer and the actinometer, that the solar energy can not build up temperature and dynamic waves in the upper strata, because the solar radiation is of such short wave lengths as to traverse the earth's atmosphere without general absorption. The outgoing radiation of much longer wave lengths from the earth's surface does, however, suffer absorption, so that such dynamic effects must belong to the lower, rather than to the higher, strata of

the atmosphere. Further studies have been made by the Austrian meteorologists, Margules, Hann, and Trabert, in a series of interesting papers<sup>2</sup>, since the year 1898.

It may be remarked that these discussions are confined to an account of the double period, apart from its natural combination with the single and triple periods. Suitable periodic variations of the coefficients, in latitude and longitude, were not to be found in the observations at the surface stations, nor at the mountain stations, and there was no data derived from the free air levels. Contact with the ground at low levels, or at high elevations, seems to have destroyed the actual temperature waves found in the free air at 400 meters and upward. It will, no doubt, now be possible to adapt these admirable mathematical studies of the Fourier series, as modified by the deflecting force of the earth's rotation and by friction, to the new temperature data pertaining to the strata up to 3000 meters elevation in the free air.

In order to place before the reader a brief summary of the facts of the barometric pressure waves which are to be explained, the following extract is quoted from my *Cloud Report*, pages 458, 459.

Analyzing the observed barometric pressure by the harmonic series,  $\Delta B = a_1 \sin(A_1 + x) + a_2 \sin(A_2 + 2x) + a_3 \sin(A_3 + 3x)$ , and discussing the constant in respect to the observations, it is noted:

1. The normal value of the amplitude of the single daily oscillation  $a_1$  is contained within the limits 0.00 and 0.50 mm. It is one-fourth to one-half the amount of  $a_2$ ; its range is wide, being two or three times the normal value; it is very different at neighboring stations, and on the same parallel of latitude; it has greater amplitudes in mountain valleys, but smaller on the seacoast and in higher latitudes; it shows a reversal of phase in the polar regions, also above a certain neutral plane at a given elevation from the ground, produced by interference with the thermic wave; it has a yearly period, with maxima in June in higher latitudes, and in March and September on the equator.

2. The normal value of the phase  $A_1$  is near  $0^\circ$ , where  $x$  is counted from midnight, and is the hour angle; it varies widely, from  $277^\circ$  to  $55^\circ$ ,  $a_1$  and  $A_1$  must have a general and a local cause. The general cause varies with the latitude and also in the year; the local cause varies with the minor convection currents, and depends upon all the meteorological features which tend to produce local convection.

3. The amplitude of the double daily wave,  $a_2$ , is the principal term, and covers the limits 0.00 to 1.00 mm. of pressure. Its range is very narrow; it decreases regularly with the height proportionally to the

pressure  $\frac{B}{760}$ ; it is very constant over the entire earth up to latitude  $55^\circ$ ; it varies with the latitude by a formula which requires an inversion of phase in the polar regions; it has a distinct variation with the year, but exhibits the following peculiarity, namely, that while the maximum insolation is in January at perihelion, the maximum of the semidiurnal wave is at the equinoxes in March and September; also the fact is remarkable that the sun in one hemisphere does not change the amplitude of the wave in the other hemisphere; it combines with the single "thermic" wave, but it is not controlled by it to any appreciable extent; it is smaller on seacoasts, islands, and on mountain tops, and is diminished a little by land and sea breezes; it is very large in mountain valleys.

4. The normal value of the phase of the double diurnal wave  $A_2$  is  $155^\circ$ , corresponding to 9<sup>h</sup> 50<sup>m</sup> a. m.; its range is very small,  $148^\circ$  to  $163^\circ$ ; it diminishes a little with the height, is retarded to  $145^\circ$  in higher latitudes, varies a little with the year, though in an opposite sense in the two hemispheres, and it is very independent of local meteorological influences.

5. The amplitude of the triple diurnal wave,  $a_3$ , is a very small quantity, being generally less than 0.10 mm. pressure. It diminishes a little with the latitude; its yearly period is very marked, and has maxima in winter and summer in both hemispheres, with minima at the equinoxes; its maximum is, however, in June, when the earth crosses the sun's equator, and not in July, when the heat is greatest in the Northern Hemisphere.

6. The phase of the triple daily period,  $A_3$ , has a normal value of  $355^\circ$ , with very small range, and with a small but very well marked yearly period.

<sup>2</sup> Ueber die tägliche Drehung der mittleren Windrichtung und über eine Oscillation der Luftmassen von halbtägiger Periode auf Berggipfeln von 2 bis 4 km. Seehöhe. J. Hann. Wien. 1902.

Same in Meteorologische Zeitschrift. Oktober, November, 1903.

Die Theorie der täglichen Luftdruckschwankung von Margules und die tägliche Oscillation der Luftmassen. W. Trabert. Met. Zeit. November, December, 1903.

<sup>1</sup> See Monthly Weather Review, December 1902, figs. 3 and 4.

TABLE 1.—*Diurnal, semidiurnal, and tri-diurnal pressure waves observed at the surface. Unit = 0.001 inch mercury.*

Hours.	January.				February.				March.				April.			
	$\Delta B.$	I.	II.	III.	$\Delta B.$	I.	II.	III.	$\Delta B.$	I.	II.	III.	$\Delta B.$	I.	II.	III.
12a	0	-1	+1	0	+1	-1	+3	-1	+3	-1	+4	0	+4	-1	+5	0
1	-3	+2	-9	+4	-2	+2	-7	+3	0	+4	-5	+1	0	+3	-3	0
2	-5	+4	-15	+6	-5	+3	-14	+6	-3	+6	-12	+3	-4	+7	-11	0
3	-6	+4	-15	+5	-7	+5	-17	+5	-4	+10	-16	+2	-5	+12	-16	-1
4	-6	+7	-13	0	-7	+8	-16	+1	-3	+13	-16	0	-2	+15	-16	-1
5	+4	+10	-9	-5	-4	+10	-11	-3	+6	+16	-10	0	+4	+16	-12	0
6	+1	+11	-3	-7	+2	+11	-4	-5	+8	+15	-5	-2	+12	+17	-5	0
7	+10	+9	+5	-4	+10	+13	-4	-7	+16	+14	+4	-2	+20	+17	+3	0
8	+20	+8	+12	0	+20	+9	+12	-1	+24	+12	+12	0	+26	+15	+11	0
9	+8	+7	+17	+4	+29	+9	+17	+3	+29	+11	+17	+1	+29	+13	+16	0
10	+31	+7	+18	+6	+32	+7	+19	+6	+29	+8	+18	+3	+27	+10	+17	0
11	+24	+5	+14	+5	+23	+4	+14	+5	+19	+5	+12	+2	+17	+6	+12	-1
12p	+2	+1	+1	0	+5	+1	+3	-1	+4	0	+4	0	+5	+1	+5	-1
1	-15	-1	-9	-5	-11	-1	-7	-3	-9	-4	-5	0	-6	-3	-3	0
2	-25	-3	-15	-7	-22	-3	-14	-5	-20	-6	-12	-2	-17	-6	-11	0
3	-24	-5	-15	-4	-27	-3	-17	-7	-27	-9	-16	-2	-26	-10	-16	0
4	-20	-7	-13	0	-25	-8	-16	-1	-24	-12	-16	0	-30	-14	-16	0
5	-14	-9	-9	+4	-18	-10	-11	+3	-25	-16	-10	+1	-28	-16	-12	0
6	-7	-10	-3	+6	-9	-11	-4	+6	-17	-15	-5	+3	-22	-17	-5	0
7	0	-11	+5	+5	-2	-12	+4	+5	-9	-15	+4	+2	-14	-16	+3	-1
8	+4	-8	+12	0	+4	-9	+11	+1	-1	-13	+12	0	-5	-15	+11	-1
9	+5	-7	+17	-5	+5	-9	+17	-3	+4	-13	+17	0	+2	-14	+16	0
10	+4	-7	+18	-7	+5	-9	+14	-5	+6	-10	+18	-2	+6	-11	+17	0
11	+3	-7	+14	-4	+4	-3	+14	-7	+5	-5	+12	-2	+6	-6	+12	0
12	0	-1	+1	0	+1	-1	+3	-1	+3	-1	+4	0	+4	-1	+5	0

Hours.	May.				June.				July.				August.			
	$\Delta B.$	I.	II.	III.	$\Delta B.$	I.	II.	III.	$\Delta B.$	I.	II.	III.	$\Delta B.$	I.	II.	III.
12a	-1	-5	+4	0	-0	-7	+6	+1	0	-6	+6	0	-1	-6	+5	0
1	-4	-1	-3	0	-4	-3	-1	0	-2	-2	-6	0	-3	-1	-2	0
2	-7	+3	-9	-1	-7	+2	-7	-2	-5	+2	-6	-1	-6	+3	-8	-1
3	-8	+8	-14	-2	-8	+6	-22	-2	-5	+7	-11	-1	-6	+6	-11	-1
4	-4	+12	-15	-1	-5	+11	-14	-2	-2	+11	-13	0	-3	-12	-14	-1
5	+4	+15	-11	0	+3	+13	-11	+1	+3	+14	-12	+1	+4	-15	-11	0
6	+11	+17	-6	0	+13	+17	-6	+2	+11	+15	-7	+3	+14	-17	-5	+2
7	+22	+18	+3	+1	+20	+17	+1	+2	+19	+16	+1	+2	+20	+18	+1	+1
8	+27	+17	+10	0	+26	+17	+8	-1	+24	+17	+7	0	+26	+18	+8	0
9	+29	+15	+14	0	+29	+16	+13	0	27	+15	+12	0	+28	+15	+13	0
10	+27	+14	+14	-1	+27	+15	+12	-2	+25	+10	+16	-1	+26	+11	+16	-1
11	+19	+11	+10	-2	+20	+11	+11	-1	+20	+9	+11	-1	+20	+10	+11	-1
12p	+9	+6	+4	-1	+11	+7	+6	-3	+11	+5	+6	0	+11	+7	+5	-1
1	-1	-2	-3	0	+2	-2	-1	+1	+2	-1	0	+1	-1	-1	-2	0
2	-11	-2	-9	0	-7	-2	-7	+2	-7	-2	-6	-3	-9	-3	-8	+2
3	-20	-7	-14	+1	-16	-6	+12	+2	-16	-7	-11	-2	-16	-6	-11	+1
4	-25	-10	-15	0	-22	-9	-14	+1	-23	-10	-13	0	-24	-10	-14	0
5	-26	-15	-11	0	-25	-14	-11	0	-26	-14	-12	0	-26	-15	-11	0
6	-22	-15	-6	-1	-25	-17	-6	-3	-24	-16	-7	-1	-24	-20	-8	-1
7	-17	-18	+3	-2	-19	-18	+1	-2	-18	-18	+1	-1	-18	-18	+1	-1
8	-8	-17	+10	-1	-11	-17	+8	-2	-10	-17	+7	0	-10	-17	+8	-1
9	-2	-16	+14	0	-3	-17	+13	-1	-3	-16	+12	+1	-3	-16	+13	0
10	+1	-13	+14	0	+1	-15	+14	+2	+6	-13	+16	+3	+1	-17	+16	+2
11	+1	-10	+10	+1	+2	-11	+11	+2	+2	-11	+11	-2	+1	-11	+11	+1
12	-1	-5	+4	0	0	-7	+6	+1	0	-6	+6	0	-1	-6	+5	0

Hours.	September.				October.				November.				December.			
	$\Delta B.$	I.	II.	III.	$\Delta B.$	I.	II.	III.	$\Delta B.$	I.	II.	III.	$\Delta B.$	I.	II.	III.
12a	0	-4	+5	-1	0	-3	+3	0	0	0	-1	+1	0	0	-1	-1
1	-2	0	-3	0	-3	+2	-7	-2	-2	+3	-9	-4	-2	+3	-10	-5
2	-5	+4	-10	+1	-5	+6	-13	-2	-5	+4	-14	-5	-4	+3	-14	-7
3	-6	+8	-15	+1	-5	+10	-16	+1	-5	+7	-15	-3	-5	+6	-15	-4
4	-3	+14	-17	0	-2	+13	-15	0	-4	+9	-13	0	-5	+9	-12	-2
5	+4	+15	-11	0	+4	+16	-10	-2	0	+12	-8	-4	-2	-10	-7	-5
6	+13	+17	-4	0	+12	+17	-3	-2	+7	+15	-2	-6	-4	+11	-1	-6
7	+21	+17	+4	0	+21	+17	+6	-2	+15	+11	+6	-2	+12	+9	+6	-3
8	+27	+18	+10	-1	+28	+16	+12	-3	+24	+11	+12	-1	+21	+9	+11	-1
9	+30	+16	+14	0	+31	+13	+16	+2	+30	+9	+17	-4	+29	+8	+16	+5
10	+28	+12	+15	+1	+29	+11	+16	+2	+29	+7	+17	-5	+30	+6	+17	+7
11	+21	+8	+12	+1	+19	+8	+10	+1	+16	+3	+10	-3	+17	+3	+10	+4
12p	+10	+5	+5	0	+6	+3	+3	0	-2	-1	-1	0	-2	+1	-1	-2
1	-2	-1	-3	0	-10	-1	-7	-2	-15	-2	-9	-4	-17	-2	-10	-5
2	-14	-4	-10	0	-21	-6	-13	-2	-23	-3	-14	-6	-24	-4	-14	-6
3	-24	-9	-15	0	-27	-9	-16	-2	-25	-8	-15	-2	-24	-6	-15	-3
4	-31	-13	-17	-1	-28	-13	-15	0	-22	-10	-13	-1	-18	-7	-12	-1
5	-26	-15	-11	0	-23	-15	-10	+2	-16	-12	-8	+4	-11	-9	-7	+5
6	-21	-18	-4	+1	-17	-16	-3	+2	-10	-12	-2	-5	-5	-11	-1	+7
7	-13	-18	+4	+1	-10	-17	+6	+1	-3	-12	+6	-3	-1	-11	+6	+4
8	-8	-18	+10	0	-4	-15	+12	0	-1	-13	+12	0	+1	-8	+11	-2
9	-2	-16	+14	0	0	-14	+16	-2	+3	-10	+17	-4	+1	-8	+16	-5
10	+1	-14	+15	0	+2	-12	+16	-2	+4	-7	+17	-6	+3	-5	+17	-6
11	+2	-10	+12	0	+1	-7	+19	-2	+3	-5	+10	-2	+3	-8	+10	-3
12	0	-4	+5	-1	0	-3	+3	0	0	0	-1	+1	0	0	-1	-1

THE DIURNAL, SEMIDIURNAL, AND TRI-DIURNAL PRESSURE WAVES COMPUTED FROM THE SURFACE OBSERVATIONS.

We can obtain the three component pressure waves from the Weather Bureau observations by employing the data contained in Mr. P. C. Day's paper, prepared by direction of Brig. Gen. A. W. Greely, "Diurnal Fluctuations of Atmospheric Pressure at twenty-nine selected stations in the United States, Washington, 1891." The tables give the local hourly corrections to the daily mean pressure; hence by changing the signs, we obtain  $\Delta B$ , the variations of the pressure for each

hour, which are to be resolved into three harmonic components by the Fourier series. Five stations were selected which are naturally comparable with Blue Hill, being located at short distances above sea level, Boston, New York, Washington, Buffalo, and Cleveland. The mean variation at each hour was computed for these stations, and it appears in the column of the Table 1 marked  $\Delta B$ , for each month of the year. In order that it might be learned whether the continental plateau stations produce the same results, the following stations, Bismarck, St. Louis, Dodge, Denver, and Salt Lake City, were computed in the same manner throughout the year. Since no

TABLE 2.—*Diurnal, semidiurnal, and tri-diurnal temperature waves, on three planes. Unit = 1 degree Fahrenheit.*

JANUARY.

Hours.	195 meters.				400 meters.				1000 meters.				Sums.			
	$\Delta T.$	I.	II.	III.	$\Delta T.$	I.	II.	III.	$\Delta T.$	I.	II.	III.	I.	II.	III.	
12a	+0.7	+1.7	-1.0	-0.0	-1.8	-0.5	-1.3	0.0	-3.4	-4.8	+0.6	+0.8	-3.6	-1.7	+0.8	
1	+1.5	+2.2	-0.9	+0.2	-2.0	+0.1	-1.9	-0.2	-3.9	-4.7	+0.4	+0.4	-2.4	-2.4	+0.4	
2	+2.0	+2.7	-0.8	+0.1	-1.9	+0.4	-2.1	-0.2	-4.1	-4.3	-0.2	0.0	-0.1	-2.7	-0.1	
3	+2.5	+3.0	-0.5	0.0	-1.3	-0.6	-1.8	-0.1	-3.8	-3.7	+0.1	-0.2	0.1	-2.2	-0.3	
4	+2.7	+3.1	-0.3	0.1	-0.2	+1.4	-0.9	-0.3	-3.1	-3.2	+0.3	-0.2	+1.3	-0.9	-0.6	
5	+2.9	+2.9	-0.1	+0.1	+1.9	+1.4	+0.4	-0.1	-1.9	-2.1	-0.2	0.0	+2.2	+0.7	0.0	
6	+2.9	+2.5	-0.4	0.0	+3.0	+1.5	+1.3	-0.2	-0.6	-0.3	-0.1	+0.2	+3.7	+1.6	+0.4	
7	+2.8	+2.0	-0.8	0.0	+3.5	+1.5	+1.9	-0.1	-0.8	-0.4	-0.1	+0.5	+3.9	+2.6	+0.8	
8	+2.7	+1.5	-1.2	0.0	+3.6	+1.4	+2.2	0.0	+2.1	+1.3	0.0	+0.8	+4.2	+3.4	+0.6	
9	+1.8	+0.1	-1.5	+0.2	+3.2	+1.3	+2.1	-0.2	-0.3	+0.5	+0.1	+0.4	+3.9	+3.7	+0.4	
10	+0.4	-0.2	-0.5	+0.1	+2.2	+1.1	+1.3	-0.2	-3.6	+3.2	+0.4	0.0	+4.1	+2.2	-0.1	
11p	-3.3	-1.0	-0.3	0.0	-1.0	+0.9	+0.2	-0.1	+1.1	+3.9	+0.4	-0.2	+3.8	+0.3	-0.3	
12	-2.7	-1.6	-1.0	0.1	-0.8	-0.2	-1.3	-0.3	+4.5	+4.1	+0.6	-0.2	+1.9	-2.4	0.0	
1	-3.3	-2.3	-0.9	-0.1	-1.8	-0.8	-2.2	-0.1	+0.1	+4.6	+4.2	+0.4	0.0	+1.9	-2.4	0.0
2	-3.5	-2.7	-0.8	0.0	-2.2	-0.3	-2.1	-0.2	+4.1	+4.0	+0.2	-0.2	0.0	-1.0	-2.7	+0.4
3	-3.5	-3.0	-0.5	0.0	-2.3	-0.6	-1.8	-0.1	+4.0	+3.4	+0.1	-0.5	-0.3	-2.2	-0.6	0.0
4	-3.3	-3.0	-0.3	0.0	-1.9	-1.0	-0.6	0.0	+3.6	+2.5	+0.3	-0.8	-1.5	-0.9	-0.8	0.0
5	-2.8	-3.1	0.1	+0.2	-1.1	-1.3	-0.4	-0.2	+2.2	+1.6	-0.2	+0.4	-2.8	+0.7	-0.4	0.0
6	-2.2	-2.7	-0.4	+0.1	-0.4	-1.5	+1.3	-0.2	+0.5	+0.5	-0.1	0.0	+3.7	+1.6	-0.1	0.0
7	-1.3	-2.1	-0.8	0.0	-0.3	-1.5	+1.9	-0.1	-1.0	-0.7	-0.1	-0.2	+4.3	-2.6	-0.3	0.0
8	-0.3	-1.4	-1.2	-0.1	-0.8	-1.1	+2.2	-0.3	-2.1	-1.9	0.0	-0.2	+4.4	+3.4	-0.6	0.0
9	+0.1	-1.3	-1.5	-0.1	+0.9	-1.3	+2.1	+0.1	-2.8	-2.9	-0.1	0.0	+5.4	+3.7	0.0	0.0
10	+0.5	0.0	+0.5	0.0	-0.4	-1.1	+1.3	-0.2	-3.2	-3.8	+0.4	+0.2	+4.9	+2.2	+0.4	0.0
11	+0.7	+1.0	-0.3	0.0	-0.6	-0.9	+0.2	-0.1	-3.4	-4.3	+0.4	+0.5	+4.2	-0.3	-0.6	0.0
12	-0.7	+1.7	-1.0	0.0	-1.8	-0.5	-1.3	0.0	-3.4	-4.8	+0.6	+0.8	-3.6	-1.7	+0.8	0.0

TABLE 2.—Diurnal, semidiurnal, and tri-diurnal temperature waves—Cont'd.

APRIL.

Hours.	195 meters.				400 meters.				1000 meters.				Sums.		
	ΔT.	I.	II.	III.	ΔT.	I.	II.	III.	ΔT.	I.	II.	III.	I.	II.	III.
12 a....	+3.1	+4.8	-1.2	-0.5	+0.6	+2.1	-0.9	-0.6	-1.9	-1.7	0.0	-0.2	+5.2	-2.1	-1.3
1.....	+4.1	+5.6	-1.4	-0.1	+1.2	+2.7	-1.3	-0.2	-1.5	-1.7	+0.2	0.0	+6.6	-2.5	-0.3
2.....	+4.8	+6.0	-1.4	+0.2	+1.7	+3.3	-1.5	-0.1	-1.3	-1.6	+0.1	+0.1	+7.7	-2.8	+0.2
3.....	+5.2	+6.1	-1.1	+0.2	+2.4	+2.8	-1.3	+0.9	-1.0	-1.2	-0.1	+0.3	+7.7	-2.5	+1.4
4.....	+5.3	+5.7	-0.6	+0.2	+2.6	+3.1	-0.9	+0.4	-0.6	-0.9	-0.1	+0.4	+7.9	-1.0	+1.0
5.....	+5.1	+4.9	+0.3	-0.1	+2.7	+2.7	-0.1	+0.1	-0.4	-0.5	-0.2	+0.3	+7.1	0.0	+0.3
6.....	+4.5	+3.9	-0.8	-0.2	+2.6	+2.6	+0.2	-0.2	-0.1	-0.2	0.0	+0.1	+6.3	+1.0	-0.3
7.....	+3.3	+2.5	-1.2	-0.4	+2.5	+1.9	+1.1	-0.5	+0.4	+0.3	+0.2	-0.1	+4.7	+2.5	-1.0
8.....	+1.8	+1.1	-1.2	-0.5	+2.0	+2.0	+0.6	-0.6	+0.9	+0.7	+0.4	-0.2	+3.8	+2.2	-1.3
9.....	+0.3	-0.6	-1.0	-0.1	+1.2	+1.3	+0.1	-0.2	+1.5	+0.9	+0.6	0.0	+1.6	+1.7	-0.3
10.....	-1.7	-2.2	+0.3	+0.2	+0.2	-0.3	+0.6	+0.1	+1.7	+1.2	+0.4	+0.1	+1.3	+1.3	-0.2
11.....	-3.6	-3.4	-0.4	+0.2	-0.9	-1.9	+0.1	+0.9	+1.8	+1.3	+0.2	+0.3	+4.0	-0.1	+1.4
12 p....	-5.4	-4.4	-1.2	+0.2	-2.4	-1.9	+0.9	+0.4	+1.9	+1.5	0.0	+0.4	+4.8	-2.1	+1.0
1.....	-6.9	-5.4	-1.4	-0.1	-3.8	-2.6	-1.3	+0.1	+1.8	+1.3	+0.2	+0.3	+6.7	-2.5	+0.3
2.....	-7.5	-5.9	-1.4	-0.2	-4.6	-2.9	-1.5	-0.2	+1.4	+1.2	-0.1	+0.1	+7.6	-2.8	-0.3
3.....	-7.4	-5.9	-1.1	-0.4	-5.0	-3.2	-1.3	-0.5	+0.9	+1.1	-0.1	-0.1	+8.0	-2.5	-1.0
4.....	-6.5	-5.4	-0.6	-0.5	-4.4	-2.9	-0.9	-0.6	+0.4	-0.7	-0.1	-0.2	+7.6	-1.6	-1.3
5.....	-4.6	-4.8	-0.3	-0.1	-2.9	-2.6	-0.1	-0.2	0.0	-0.2	-0.2	0.0	+7.2	0.0	-0.3
6.....	-2.6	-3.6	-0.8	-0.2	-2.2	-2.3	+0.2	-0.1	-0.1	0.0	0.0	+0.1	+5.9	+1.0	-0.2
7.....	-0.9	-2.3	-1.2	+0.2	-2.3	-1.7	+1.1	+0.9	0.0	-0.5	+0.2	+0.3	+4.5	+2.5	+1.4
8.....	+0.6	-0.8	-1.2	+0.2	+0.9	-0.1	+0.6	+0.4	-0.1	-0.9	+0.4	+0.4	+1.8	+2.2	+1.0
9.....	+1.6	+0.7	-1.0	-0.1	+1.3	+1.1	+0.1	+0.1	-0.1	-0.3	+0.6	+0.3	+0.5	+1.7	+0.3
10.....	+2.3	+2.2	-0.3	-0.2	+1.3	+0.9	+0.6	-0.2	-1.0	-1.5	+0.4	-0.1	+1.6	+1.3	-0.3
11.....	+2.8	+3.6	-0.4	-0.4	+1.0	+1.4	+0.1	-0.5	-1.5	-1.6	-0.2	-0.1	+3.4	-0.1	-1.0
12.....	+3.1	+4.8	-1.2	-0.5	+0.6	+2.1	-0.9	-0.6	-1.9	-1.7	0.0	-0.2	+5.2	-2.1	-1.3

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12 a....	+4.5	+5.3	-0.6	-0.2	-0.5	-0.2	-0.5	+0.2	-0.8	-0.7	-0.2	+0.1	+4.4	-1.3	+0.1
1.....	+4.6	+6.1	-1.0	-0.5	-0.7	+0.3	-1.3	+0.3	-0.8	-0.4	-0.5	+0.1	+6.0	-2.8	-0.1
2.....	+4.7	+6.4	-1.3	-0.4	-0.9	+0.6	-1.7	+0.2	-0.8	-0.1	-0.8	+0.1	+6.9	-3.8	-0.1
3.....	+4.8	+6.4	-1.3	-0.3	-0.8	+1.1	-1.8	-0.1	-0.7	-0.3	-1.0	0.0	+7.8	-4.1	-0.4
4.....	+4.8	+5.9	-1.0	-0.1	-0.5	+1.2	-1.5	-0.2	-0.3	-0.8	-1.0	-0.1	+7.9	-3.5	-0.4
5.....	+4.5	+5.0	-0.5	0.0	-0.5	+1.4	-0.7	-0.2	+0.6	-1.1	-0.5	0.0	+7.5	-1.7	-0.2
6.....	+3.9	+4.7	-0.2	0.0	-1.6	+1.3	-0.4	-0.1	+1.4	-1.1	-0.2	+0.1	+7.1	+0.8	0.0
7.....	+2.8	+2.3	-0.7	-0.2	-2.8	+1.3	+1.3	+0.2	-2.2	-1.4	-0.7	+0.1	+5.0	+2.7	+0.1
8.....	+1.5	+0.7	-1.0	-0.2	-3.6	+1.3	+1.1	+0.2	-2.7	-1.5	-1.1	+0.1	+3.5	+4.2	+0.1
9.....	-0.5	-0.9	-0.9	-0.5	-3.3	+1.0	+2.0	+0.3	-2.7	-1.4	-1.2	+0.1	+1.5	+1.1	-0.1
10.....	-2.5	-2.5	+0.4	-0.4	-2.4	+0.7	+1.5	-0.2	-2.1	-1.1	+0.9	-0.1	-0.7	+2.8	-0.1
11.....	-4.2	-3.1	-0.2	-0.3	-0.8	+0.2	-0.7	-0.1	+1.4	-1.0	-0.4	0.0	-1.9	+0.9	-0.4
12 p....	-5.6	-4.9	-0.6	-0.1	-0.5	+0.2	-0.5	-0.2	+0.5	-0.8	-0.2	+0.1	+3.9	-1.3	-0.4
1.....	-6.6	-5.5	-1.0	0.0	-1.8	-0.3	-1.3	-0.2	-0.1	+0.4	-0.5	0.0	+5.5	-2.8	-0.2
2.....	-7.2	-5.9	-1.3	0.0	-2.5	-0.7	-1.7	-0.1	-0.8	-0.1	-0.8	+0.1	+6.7	-3.8	0.0
3.....	-7.3	-5.8	-1.3	-0.2	-2.8	-1.2	-1.8	+0.2	-1.2	-0.3	-1.0	-0.1	+7.3	-4.1	+0.1
4.....	-6.7	-5.5	-1.0	-0.2	-2.5	-1.2	-1.5	+0.2	-1.7	-0.8	-1.0	+0.1	+7.5	-3.5	+0.1
5.....	-5.5	-4.5	-0.5	-0.5	-1.8	-1.4	-0.7	+0.3	-1.6	-1.2	-0.5	+0.1	+7.1	-1.7	-0.1
6.....	-3.5	-3.3	-0.2	-0.4	-0.9	-1.5	-0.4	+0.2	-1.1	-1.4	+0.2	+0.1	+6.2	-0.8	-0.1
7.....	-1.5	-1.9	-0.7	-0.3	-0.2	-1.4	+1.3	-0.1	-0.8	-1.5	-0.7	0.0	+4.8	+2.7	-0.4
8.....	+0.5	-1.4	-1.0	-0.1	-0.5	-1.4	+1.1	-0.2	-0.5	-1.5	-1.1	-0.1	+4.3	+2.4	-0.4
9.....	+2.2	+1.3	-0.9	0.0	-0.6	-1.2	+2.0	-0.2	-0.4	-1.6	-1.2	0.0	+1.5	+4.1	-0.2
10.....	+3.2	+3.6	-0.4	0.0	-0.5	-0.9	+1.5	-0.1	-0.4	-1.4	+0.9	+0.1	+1.3	+2.8	0.0
11.....	+3.9	+4.3	-0.2	-0.2	-0.5	-0.4	+0.7	+0.2	-0.6	-1.1	-0.4	+0.1	+2.8	+0.9	+0.1
12.....	+4.5	+5.3	-0.6	-0.2	-0.5	-0.2	-0.5	+0.2	-0.8	-0.7	-0.2	+0.1	+4.4	-1.3	+0.1

JUNE.

12 a....	+4.2	+5.5	-0.6	-0.7	+1.7	+2.6	-0.3	-0.6	-1.4	+1.1	+0.5	-0.2	+9.2	-0.4	-1.5
1.....	+4.9	+5.7	-0.5	-0.3	-1.9	+3.2	-0.8	-0.5	+1.7	+1.5	+0.2	0.0	+10.4	-1.1	-0.8
2.....	+5.3	+6.7	-1.3	-0.1	+2.3	+3.5	-1.1	-0.1	+2.1	+2.2	-0.2	+0.1	+12.4	-2.6	-0.1
3.....	+5.6	+6.8	-1.3	0.0	+2.6	+3.6	-1.3	+0.3	+2.4	+2.4	-0.4	+0.4	+12.8	-3.0	+0.7
4.....	+5.3	+6.4	-1.2	+0.1	+2.7	+3.6	-1.3	+0.4	+2.4	+2.4	-0.5	+0.5	+12.5	-3.0	+1.0
5.....	+4.9	+5.2	-0.5	-0.2	-2.8	+3.9	-1.3	+0.2	+2.1	+2.2	-0.3	+0.5	+11.3	-2.1	+0.9
6.....	+3.9	+5.2	+0.1	-0.4	-2.7	-2.7	+1.0	-0.1	+2.3	+2.1	0.0	+0.2	+8.0	+0.2	-0.3
7.....	+2.8	+2.9	-0.5	-0.6	-2.5	+1.8	+1.0	-0.3	+2.0	+1.6	+0.4	0.0	+6.3	+1.9	-0.9
8.....	+1.3	+1.2	-0.8	-0.7	+1.7	+1.1	+1.2	-0.6	+1.4	+1.2	-0.4	-0.2	+3.5	+2.4	-1.5
9.....	+0.1	-0.4	-0.8	-0.3	+0.9	+1.3	+1.1	-0.5	+1.2	+0.4	+0.8	0.0	+1.3	+2.7	-0.8
10.....	-1.8	-2.1	-0.4	-0.1	0.0	-0.7	+0.8	-0.1	+0.6	-0.1	+0.6	-0.1	-2.9	+1.8	-0.1
11.....	-3.7	-3.3	-0.1	0.0	-1.1	-1.7	+0.3	+0.2	-0.6	-0.4	+0.4	+0.4	+6.1	+0.8	+0.7
12 p....	-5.3	-4.8	-0.6	-0.1	-2.3	-2.4	-0.3	+0.4	-0.4	-1.4	+0.5	-0.5	+8.6	-0.4	+1.0
1.....	-5.8	-5.5	-0.5	+0.2	-3.5	-2.9	-0.8	-0.2	-1.4	-2.1	+0.2	+0.3	+10.5	-1.1	+0.9
2.....	-7.8	-6.1	-1.3	-0.4	-4.5	-3.3	-1.1	-0.1	-2.4	-2.4	-0.2	+0.2	+11.8	-2.6	-0.3
3.....	-8.1	-6.2	-1.3	-0.6	-5.2	-3.6	-1.3	-0.3	-3.1	-2.7	-0.4	0.0	+12.5	-3.0	+0.9
4.....	-7.6	-5.7	-1.2	-0.7	-5.3	-3.4	-1.3	-0.6	-3.5	-2.8	-0.5	-0.2	+10.9	-3.0	+1.5
5.....	-5.8	-5.0	-0.5	-0.3	-1.3	-2.5	-1.3	-0.5	-3.0	-2.7	-0.3	0.0	+10.2	-2.1	-0.8
6.....	-3.8	-3.3	+0.1	-0.1	-2.5	-2.5	+1.0	-0.1	-2.3	-2.4	0.0	+0.1	+8.7	+0.2	-0.1
7.....	-1.8	-2.3	+0.5	0.0	-0.5	-1.8	+1.0	-0.3	-1.3	-2.1	+0.4	+0.4	+6.2	+1.9	+0.7
8.....	+0.2	-0.7	-0.8	+0.1	+0.7	-0.9	+1.2	-0.4	-0.6	-1.5	-0.4	+0.5	+3.1	+2.4	+1.0
9.....	+1.5	+0.5	+0.8	+0.2	-1.3	0.0	+1.1	+0.2	-0.4	-0.9	+0.8	+0.6	+0.4	+2.7	+0.9
10.....	+2.6	+2.5	+0.4	-0.4	+1.5	+0.8	+0.8	-0.1	+0.7	-0.1	+0.6	-0.2	+3.3	+1.8	-0.3
11.....	+3.5	+3.0	+0.1	-0.6	+1.7	+1.7	+0.3	-0.3	+1.2	+0.8	0.4	0.0	+5.5	+0.8	-0.9
12.....	+4.2	+5.5	-0.6	-0.7	+1.7	+2.6	-0.3	-0.6	-1.4	+1.1	+0.5	-0.2	+9.2	-0.4	-1.5

important differences exist between these two sets of stations, the plateau computation is not reproduced in this paper. The separation of the wave of  $\Delta B$  into components was accomplished by the precepts,

$$\text{semidiurnal wave} = \text{II} = \frac{12a + 12p}{2}, \frac{1a + 1p}{2}, \text{ etc.,}$$

$$\text{tridiurnal wave} = \text{III} = \frac{12a + 8a + 4p}{3}, \frac{1a + 9a + 5p}{3}, \text{ etc.,}$$

$$\text{diurnal} = \text{I} = \Delta B - (\text{II} + \text{III}) \text{ at each hour.}$$

The pressure  $\Delta B$ , Table 1, and the temperature  $\Delta T$ , Table 2, were each computed in the same way.  $\Delta B$  is given in units

TABLE 2.—Diurnal, semidiurnal, and tri-diurnal temperature waves—Cont'd.

JULY.

Hours.	195 Meters.				400 Meters.				1000 Meters.				Sums.		
	ΔT.	I.	II.	III.	ΔT.	I.	II.	III.	ΔT.	I.	II.	III.	I.	II.	III.
12 a.	+3.8	+5.2	-1.2	-0.2	+0.2	+0.8	-0.4	-0.2	0.0	+0.3	-0.1	-0.2	+6.3	-1.7	-0.6
1.	+4.5	+5.9	-1.4	0.0	+1.2	+1.5	-0.2	-0.1	+0.8	+0.8	+0.1	-0.1	+8.2	-1.5	-0.2
2.	+5.0	+6.3	-1.3	0.0	+2.1	+2.1	0.0	0.0	+1.6	+1.5	+0.2	-0.1	+9.9	-1.1	-0.1
3.	+5.2	+6.5	-1.2	0.0	+2.9	+2.6	+0.2	+0.1	+2.3	+2.3	+0.1	-0.1	+11.4	-0.9	0.0
4.	+5.3	+6.2	-0.7	-0.2	+3.3	+3.1	+0.2	0.0	+2.8	+2.5	+0.2	+0.1	+11.8	-0.3	-0.1
5.	+5.0	+5.3	-0.1	-0.2	+3.3	+3.0	+0.2	+0.1	+2.8	+2.7	-0.1	+0.1	+11.0	0.0	+0.1
6.	+4.4	+4.4	-0.6	-0.3	+3.1	+2.9	+0.1	+0.1	+2.6	+2.7	-0.2	+0.1	+10.0	+0.5	-0.4
7.	+3.5	+2.5	-1.3	-0.3	+2.8	+2.6	+0.1	+0.1	+2.4	+2.6	-0.2	0.0	+7.7	+1.2	-0.2
8.	+2.4	+1.2	-1.4	-0.2	+2.1	+2.4	-0.1	-0.2	+1.8	+2.2	-0.2	-0.2	+5.8	+1.1	-0.6
9.	0.7	+0.5	+1.2	0.0	+1.5	+1.5	-0.1	-0.1	+1.6	+1.5	+0.1	-0.1	+2.5	+1.4	-0.2
10.	-1.8	-1.6	-0.2	0.0	+0.7	+0.6	+0.1	0.0	+0.8	+1.0	-0.1	-0.1	0.0	-0.2	-0.1
11.	-4.1	-3.6	-0.5	0.0	0.0	0.0	1.0	0.0	0.2	0.4	-0.1	-0.1	-3.3	-0.6	0.0
12 p.	-6.2	-4.8	-1.2	-0.2	-1.0	-0.6	-0.4	0.0	-0.2	-0.2	-0.1	-0.1	-5.6	-1.7	-0.1
1.	-7.2	-5.6	-1.4	-0.2	-1.5	-1.4	-0.2	-0.1	-0.7	-1.0	-0.1	-0.2	-8.0	-1.5	-0.1
2.	-7.6	-5.7	-1.3	-0.6	-2.1	-2.2	0.0	-0.1	-1.4	-1.7	-0.2	-0.1	-9.6	-1.1	-0.4
3.	-7.5	-6.0	-1.2	-0.3	-2.6	-2.9	+0.2	+0.1	-2.1	-2.2	-0.1	0.0	-11.1	-0.9	-0.2
4.	-6.7	-5.8	-0.7	-0.2	-2.9	-2.9	+0.2	-0.2	-2.4	-2.4	-0.2	-0.2	-11.1	-0.3	-0.6
5.	-5.2	-5.1	-0.1	0.0	-3.0	-3.1	+0.2	-0.1	-2.9	-2.7	-0.1	-0.1	-10.9	0.0	-0.2
6.	-3.2	-3.8	+0.6	0.0	-2.9	-3.0	+0.1	0.0	-2.9	-2.6	-0.2	-0.1	-9.4	+0.5	-0.1
7.	-1.0	-2.3	+1.3	0.0	-2.7	-2.9	+0.1	-0.1	-2.8	-2.5	-0.2	-0.1	-7.7	+1.2	0.0
8.	-0.4	-0.8	+1.4	-0.2	-2.2	-2.1	-0.1	0.0	-2.2	-2.1	-0.2	-0.1	-5.0	+1.1	-0.1
9.	-1.7	-0.7	+1.2	-0.2	-1.4	-1.6	+0.1	+0.1	-1.5	-1.8	+0.1	-0.2	-2.7	+1.4	+0.1
10.	-1.5	-2.3	-0.2	-0.6	-0.6	-0.8	+0.1	+0.1	-0.9	-0.9	-0.1	-0.1	-0.6	-0.2	-0.4
11.	-3.1	-2.9	-0.5	-0.3	0.0	-0.1	0.0	-0.1	-0.3	-0.4	-0.1	0.0	-3.4	-0.6	-0.2
12.	-3.8	-5.2	-1.2	-0.2	+0.2	+0.8	-0.4	-0.2	0.0	+0.3	-0.1	-0.2	+6.3	-1.7	-0.6

TABLE 2.—*Diurnal, semidiurnal, and tri-diurnal temperature waves—Cont'd.*

OCTOBER.													
Hour.	195 meters.				400 meters.				1000 meters.				Sums.
	$\Delta T$ .	I.	II.	III.	$\Delta T$ .	I.	II.	III.	$\Delta T$ .	I.	II.	III.	I. II. III.
12 a...	+1.6	-3.0	-1.2	-0.2	-1.3	-0.5	-0.8	0.0	-2.1	-1.5	-0.8	+0.2	+1.0 -2.8 0.0
1...	+2.3	-3.7	-1.2	-0.2	-1.6	-0.6	-1.2	+0.2	-2.1	-1.5	-0.9	+0.3	+1.6 -3.3 +0.3
2...	+2.9	-3.8	-0.9	-0.0	-1.9	-0.7	-1.4	+0.2	-2.0	-1.4	-0.8	+0.2	+1.7 -3.1 +0.4
3...	+3.4	-4.0	0.6	0.0	-1.8	-0.7	-1.2	+0.1	-1.7	-1.2	-0.6	+0.1	+2.1 -2.4 +0.2
4...	+3.6	-3.4	+0.1	+0.1	-2.1	-0.7	-1.2	-0.2	-0.9	-1.0	0.0	+0.1	+1.7 -1.1 0.0
5...	+3.5	-2.9	+0.6	0.0	-0.6	-0.1	-0.1	0.0	-0.8	+0.6	+0.2	+1.5	+1.2 +0.1
6...	+2.9	-2.1	+0.9	-0.1	+0.3	-0.4	+0.7	0.0	+0.6	-0.3	+0.9	0.0	+1.4 +2.5 -0.1
7...	+2.2	-1.5	+1.0	-0.3	+1.0	-0.3	+1.4	-0.1	+1.2	+0.1	+1.1	0.0	+1.3 +3.5 -0.4
8...	+1.1	+0.4	-0.9	-0.2	+1.7	0.0	+1.7	0.0	+1.7	+0.3	+1.2	+0.2	+0.7 +3.8 0.0
9...	-0.4	-0.6	-0.4	-0.2	+1.7	-0.1	+1.6	-0.2	+1.8	+0.5	+1.0	+0.3	+0.2 +3.0 +0.3
10...	-1.6	-1.5	-0.1	0.0	+1.3	+0.2	+0.9	+0.3	+1.5	+1.0	+0.3	+0.2	+0.3 +1.1 -0.4
11...	-3.2	-2.4	-0.8	0.0	+0.5	+0.6	-0.2	+0.1	+1.0	+1.3	-0.4	+0.1	+0.5 -1.4 +0.2
12 p...	-4.0	-2.9	-1.2	+0.1	-0.3	+0.7	-0.8	-0.2	+0.5	-1.2	-0.8	+0.1	+1.0 -2.8 0.0
1...	-4.6	-3.3	-1.3	0.0	-0.7	+0.4	-1.2	+0.1	+0.4	+1.1	-0.9	+0.2	+1.8 -3.3 +0.1
2...	-4.6	-3.6	-0.9	-0.1	-0.8	+0.6	-1.4	0.0	+0.4	+1.2	-0.8	0.0	+1.8 -3.1 -0.1
3...	-4.4	-3.6	-0.6	-0.2	-0.6	+0.7	-1.2	-0.1	+0.5	+1.1	-0.6	0.0	+1.8 -2.4 -0.4
4...	-3.4	-3.3	-0.1	-0.2	-0.3	+0.9	-1.2	0.0	+0.9	+0.7	0.0	+0.2	+1.7 -1.1 0.0
5...	-2.4	-2.8	+0.6	-0.2	+0.5	+0.4	-0.1	+0.2	+1.1	+0.2	+0.6	+0.3	+2.2 +1.2 +0.3
6...	-1.2	-2.2	+0.9	+0.1	+1.1	+0.2	+0.7	+0.2	+1.1	0.0	+0.9	+0.2	+2.0 +2.5 +0.4
7...	-0.2	-1.2	+1.0	0.0	+1.7	+0.2	+1.4	+0.1	+0.9	-0.3	+1.1	+0.1	+1.3 +3.5 +0.2
8...	+0.6	-0.4	+0.9	+0.1	+1.7	+0.2	+1.7	-0.2	+0.7	-0.6	+1.2	+0.1	+0.8 +3.8 0.0
9...	+1.1	+0.7	+0.4	0.0	+1.5	-0.2	+1.6	+0.1	+0.1	-1.1	+1.0	+0.2	+0.6 +3.0 +0.1
10...	+1.4	+1.6	-0.1	-0.1	+0.5	-0.4	+0.9	0.0	-0.9	-1.2	+0.3	0.0	+0.0 +1.1 -0.1
11...	+1.6	+2.7	-0.8	-0.3	-0.8	-0.5	-0.2	-0.1	-1.8	-1.4	-0.4	0.0	+0.8 -1.4 -0.4
12...	+1.6	+3.0	-1.2	-0.2	-1.3	-0.5	-0.8	0.0	-2.1	-1.5	-0.8	+0.2	+1.0 -2.8 0.0
NOVEMBER.													
12 a...	+2.0	+2.8	-1.1	+0.3	-1.0	-1.1	-0.5	-0.6	-0.1	-0.1	-0.4	+0.4	+1.6 -2.0 +1.3
1...	+2.1	+3.4	-1.5	+0.2	-1.6	-1.2	-0.8	-0.4	-0.2	-0.1	-0.5	+0.4	+2.1 -2.8 +1.0
2...	+2.2	+3.6	-1.4	0.0	-1.9	-1.0	-0.8	0.0	-0.4	-0.0	-0.5	+0.4	+2.5 -2.7 +0.8
3...	+2.4	+3.9	-1.2	-0.3	-2.0	-1.0	-0.7	-0.3	-0.6	0.1	-0.4	+0.1	+2.8 -2.3 +0.7
4...	+2.8	+3.3	-0.4	-0.1	-2.0	-0.8	-0.5	-0.7	-0.7	0.0	-0.3	-0.4	+2.5 -1.2 -1.2
5...	+3.0	+3.6	-0.1	-0.5	-0.9	-0.6	-1.0	-0.4	-1.2	-0.1	-0.5	-0.6	+2.7 -0.5 -1.5
6...	+3.2	+2.9	+0.2	-0.7	-0.2	-0.8	-0.1	-0.3	0.0	-0.3	-0.2	+0.9	+2.7 +1.6 -0.1
7...	+3.5	+2.2	+0.5	+0.1	-0.3	-0.9	-1.1	-0.8	0.0	+0.6	+0.2	+2.2	+2.2 +0.9 +0.7
8...	+3.0	+1.2	+1.5	+0.3	-1.3	-0.3	-1.0	-0.6	-1.2	0.0	+0.8	+0.4	+1.5 +3.3 +1.3
9...	+1.8	+0.4	+1.2	-0.2	-1.7	-0.6	-0.7	-0.4	-1.0	0.0	+0.6	+0.4	+1.0 +2.5 +1.0
10...	-0.1	-0.7	-0.6	-0.3	-0.5	-0.9	-1.0	-0.5	-0.2	-0.2	-0.1	+0.4	+0.4 +0.9 +0.1
11...	-2.3	-1.6	-0.4	-0.3	-0.5	-1.1	-0.3	-0.3	0.0	-0.1	0.0	-0.1	+0.4 -0.7 -0.7
12 p...	-4.2	-3.0	-1.1	-0.1	-1.2	-0.5	-0.7	-0.7	-0.1	-0.4	-0.4	-0.4	+1.7 -2.0 -1.2
1...	-5.0	-3.0	-1.5	-0.4	-1.3	-0.8	-0.8	-0.1	-0.5	-0.0	-0.5	0.0	+2.0 -2.8 -1.5
2...	-5.0	-3.4	-1.4	-0.2	-1.3	-1.0	-0.8	-0.4	-0.2	-0.0	-0.3	0.0	+2.2 -2.7 -1.3
3...	-4.8	-3.7	-1.2	-0.1	-1.0	-0.9	-0.7	-0.4	-0.2	0.0	-0.4	+0.2	+2.8 -2.3 +0.7
4...	-4.0	-3.9	-0.4	-0.3	-1.0	-0.9	-0.5	-0.6	-0.2	-0.1	-0.3	+0.4	+2.4 -1.2 +1.3
5...	-3.2	-3.3	-0.1	-0.2	-0.9	-0.5	-1.1	-0.4	-0.3	+0.4	-0.3	+0.4	+2.4 +0.5 +1.0
6...	-2.2	-2.7	+0.5	0.0	-0.9	-0.1	-0.9	-0.3	-0.2	+0.0	-0.1	+0.3	+2.7 +1.6 +0.7
7...	-1.1	-2.0	+1.2	-0.3	-0.6	-0.2	-1.1	-0.3	-0.3	-0.2	+0.0	-0.1	+2.4 +1.6 +0.6
8...	0.0	-1.4	+1.5	-0.1	0.0	-0.2	-0.9	-0.7	-0.3	-0.1	-0.8	+0.1	+2.7 +3.2 +1.2
9...	+0.6	-0.1	+1.2	-0.5	-0.4	0.7	-0.7	-0.4	+0.2	+0.2	-0.6	0.0	+0.6 +2.5 +1.5
10...	+1.2	+0.8	-0.6	-0.2	-0.8	-1.0	+0.1	+1.1	-0.1	-0.1	+0.2	0.0	+0.3 +0.9 -0.1
11...	+1.6	+1.9	-0.4	+0.1	-1.0	-1.1	-0.3	-0.4	0.0	-0.2	0.0	+0.2	+0.6 -0.7 -0.7
12...	+2.0	+2.8	-1.1	+0.3	-1.0	-1.1	-0.5	-0.6	-0.1	-0.1	-0.4	+0.4	+1.6 -2.0 +1.3
DECEMBER.													
12 a...	+1.2	+1.8	-0.8	+0.2	-1.7	-2.4	+0.2	-0.5	+2.1	+2.4	0.0	-0.3	+1.8 -0.6 +0.4
1...	+1.3	+2.4	-1.3	+0.2	-2.0	-2.3	-0.1	-0.4	+2.3	+2.4	+0.2	-0.3	+2.5 -1.2 +0.3
2...	+1.5	+2.6	-1.3	+0.2	-2.1	-2.0	-0.2	-0.1	+2.4	+2.2	+0.3	-0.1	+2.8 -1.2 +0.2
3...	+1.9	+3.1	-1.1	-0.1	-2.1	-1.7	-0.3	-0.1	+2.2	+1.9	+0.3	0.0	+3.3 -1.1 -0.2
4...	+2.3	+3.3	-0.8	-0.2	-2.0	-1.3	-0.4	-0.3	+2.0	+1.5	+0.3	+0.2	+3.5 -0.9 -0.3
5...	+3.0	+3.2	0.0	-0.2	-0.9	-0.8	0.0	-0.1	+1.3	+1.1	-0.1	+0.1	+3.5 +0.1 -0.2
6...	+3.2	+2.7	+0.6	-0.1	-0.2	-0.2	+0.2	-0.1	+0.3	-0.3	-0.3	-0.1	+2.8 +0.5 0.0
7...	+3.2	+2.1	+1.1	0.0	+1.2	-0.5	-0.4	-0.3	-1.2	-0.2	-0.6	-0.4	+2.4 +0.9 -0.1
8...	+3.1	+1.3	+1.6	+0.2	-2.0	-1.0	-0.5	-0.5	-1.7	-1.8	-0.6	-0.3	+1.5 +1.5 +0.4
9...	+2.4	+0.9	+1.3	+0.2	-2.2	-1.3	-0.5	-0.4	-2.0	-1.2	-0.5	-0.3	+1.0 +1.3 +0.3
10...	+1.1	0.0	+0.9	-0.2	-2.2	-1.7	-0.4	-0.1	-2.1	-1.7	-0.8	-0.1	+0.0 +1.0 +0.2
11...	-1.3	-1.0	-0.2	-0.1	-2.1	-2.0	-0.2	-0.1	-2.2	-2.0	-0.2	0.0	-1.0 -0.2 -0.2
12 p...	-2.8	-3.4	-0.8	-0.2	-2.0	+2.0	-0.2	-0.3	-2.1	-2.3	0.0	+0.2	+3.6 -0.6 -0.3
1...	-3.8	-4.9	-1.3	-0.2	-1.9	+2.1	-0.1	-0.1	-2.0	-2.3	+0.2	-0.1	+5.1 -1.2 -0.2
2...	-4.1	-5.3	-1.3	-0.1	-1.8	+1.8	-0.2	-0.2	-1.9	-2.3	+0.3	-0.1	+5.8 -1.2 -0.2
3...	-4.1	-5.2	-1.1	0.0	-1.6	+1.6	-0.3	-0.3	-1.7	-1.6	+0.3	-0.4	+5.2 -1.1 -0.1
4...	-3.8	-4.8	-0.8	-0.2	-1.3	+1.2	-0.4	-0.5	-1.4	-1.4	+0.3	-0.3	+5.0 -0.9 +0.4
5...	-3.0	-3.2	0.0	-0.2	-0.9	+0.5	0.0	-0.4	-1.1	-0.9	+0.1	-0.3	+3.6 +0.1 +0.3
6...	-2.0	-2.8	-0.6	-0.2	+0.1	0.2	-0.2	-0.1	-0.5	-0.1	-0.3	-0.1	+3.1 +0.5 +0.2
7...	-1.0	-1.5	-0.6	-0.1	-0.4	-0.7	-0.4	-0.1	-0.1	+0.5	-0.6	0.0	+1.7 +0.9 -0.2
8...	0.0	-1.4	-1.6	-0.2	-1.0	-1.2	-0.5	-0.3	+0.6	+1.0	-0.6	+0.2	+1.6 +1.5 -0.3
9...	-0.2	-0.9	+1.3	-0.2	-1.2	-1.6	-0.5	-0.1	+1.1	+1.5	-0.5	-0.1	+1.0 +1.3 -0.2
10...	-0.6	-0.2	+0.9	-0.1	-1.5	-2.1	-0.4	-0.2	+1.6	-2.0	-0.3	-0.1	+0.1 +1.0 0.0
11...	-0.9	+1.1	-0.2	0.0	-1.8	-2.3	+0.2	+0.3	+1.8	-2.4	-0.2	-0.4	+1.2 -0.2 -0.1
12...	+1.2	+1.8	-0.8	+0.2	-1.7	-2.4	+0.2	-0.5	+2.1	+2.4	0.0	-0.3	+1.8 -0.6 +0.4

the year. The following characteristics of these waves may be noted.

*Diurnal wave.*—In January the amplitude,  $a$ , is about 0.011 inch, and this increases to 0.018 in August, which seems to be the maximum. The phase of the maximum in January is at 6-7 a. m., and that of the minimum is at 6-7 in the evening. The morning maximum phase is, apparently, about one hour later, 7-8 a. m. in the summer, and the evening minimum phase is, also, one hour later, 7-8 p. m. Thus, there is a slight advance of one hour in the times of maximum and minimum in passing from the cold season, with the sun in the

Southern Hemisphere, to the warm season, with the sun in the Northern Hemisphere.

*Semidiurnal wave.*—The two maxima occur with remarkable steadiness at about 10 a. m. and 10 p. m. throughout the year, though they are a little later in the summer than in the winter. The minima occur at 3-4 a. m. and 3-4 p. m. in the winter, and about one hour later 4-5 a. m. and 4-5 p. m. in the summer. The ascending branch of the curve is, therefore, a little less inclined than the descending branch during the winter, but in summer they are quite symmetrical. The amplitude of the curve is about 0.018 in January and somewhat less in the summer, 0.014 in June, 0.015 in July.

*Tri-diurnal wave.*—There is much more fluctuation in this minor wave than in the two others just described. In December, January, and February the amplitude is about 0.006, with maxima at 2 a. m., 10 a. m., 6 p. m., and minima at 6 a. m., 2 p. m., 10 p. m. On the other hand, in the summer the amplitude is about one-third as great, 0.002, but the phase is reversed so that the maxima occur at 7 a. m., 3 p. m., 11 p. m., with the minima at 3 a. m., 11 a. m., 7 p. m. The change of phase appears to take place between March-April, August-September, so that the larger amplitude is developed while the sun is in the Southern Hemisphere, and the smaller while it is in the northern, the transition taking place at the equinoxes as the sun crosses the equator. This is the third instance in which an inversion phenomena has been detected in the earth's atmosphere, due the orbital solar action: (1) The inversion of the magnetic and meteorological elements as described in my Bulletin No. 21; (2) the inversion or surging of the atmosphere as to its temperature between the Tropics and the temperate zones, and as to its pressure between the Eastern and the Western hemispheres, as shown in the MONTHLY WEATHER REVIEW, November 1903; and (3) in the tri-diurnal pressure wave as exhibited in this paper. Whatever may be the causes of these phenomena of inversion it is evident that the mere interference of waves of different periods can not be the sole cause. The subject will require careful and exhaustive investigation of the numerous forces operating in the complex circulations of the solar and terrestrial atmospheres.

#### THE DIURNAL, SEMIDIURNAL, AND TRI-DIURNAL TEMPERATURE WAVES IN THE LOWER STRATA OF THE ATMOSPHERE.

An inspection of the temperature curves given in the preceding paper, MONTHLY WEATHER REVIEW, February, 1905, makes it evident that the temperature waves in the successive strata of the lower atmosphere differ very much from the wave observed at the surface. We may suppose that the pressure waves are closely connected with the temperature variations in the lower strata, and that the changes in the density produced by the variations in temperature become converted into pressure changes in part by thermodynamic processes. The subject is, of course, complex, and its final solution will require more detailed examination than it has been possible to make at this time. I have decided to execute a rough sort of integration of the entire temperature effect, by computing the components for the curves deduced on the planes at 195, 400, and 1000 meters elevation. The agreement between this result and the actual one existing in the atmosphere from the surface to 3400 meters can be only approximate, but the outcome serves to indicate that the temperature waves in the free air are the direct cause of the pressure waves as a density rather than as a dynamic effect. The temperatures on these three planes were scaled from the diagrams, each one was separated into its I, II, III components, and then the sums for each type on these three planes were computed. The details of this work are given in Table 2, since they are of general interest, and the second section of the diagrams under each month in figs. 26-37 gives the corresponding temperature curves. I repeat the statement, that for convenient comparison of the temperature

waves with the pressure waves the numerical signs have been reversed throughout the temperature computation.

*Diurnal wave.*—These temperature waves have been constructed without using the surface temperatures, and this implies that the temperatures in the several strata are chiefly concerned in generating the pressure waves that are observed at the respective elevations. Of course some additional influence must be expected to work in from the adjacent strata not here reckoned in the integration, and therefore the results here discussed do not exhaust the entire scope of the available sources of inquiry. A close approximation to a parallelism between the pressure and the temperature systems is certainly indicated. In January, February, and March the diurnal curves of temperature and pressure are in close agreement as to amplitude and phase, and reversing the sign of  $\Delta T$ , we obtain the relation,

$$-4^{\circ} \Delta T \propto +0.010 \Delta B, \text{ or } -1^{\circ} F \propto +0.0025 \text{ inch.}$$

With the approach to summer the curve of temperature increases in amplitude more rapidly than the pressure curve, and the phase of maximum and of minimum in July and August is about three or four hours earlier, 4 a. m. for temperature and 7 a. m. for pressure, or 3:30 p. m. for temperature and 7:30 p. m. for pressure. The semidiurnal temperature waves are, however, smaller than would be expected and possibly I have not obtained exactly the correct temperature curves to resolve into components in these two months. We have an approximate relation,

$$-12^{\circ} \Delta T \propto +0.017 \Delta B, \text{ or } -1^{\circ} F \propto +0.0014 \text{ inch.}$$

It follows that in summer the influence of one degree of temperature to change the pressure is about one-half as much as it is in the winter. This implies a series of complex functions which it is not possible to discuss in this place.

*Semidiurnal wave.*—The most important fact brought out by this computation is that a true semidiurnal wave of temperature is developed in the lower strata whose phase for the maximum ordinate persists steadily throughout the year at 8 a. m. and 8 p. m., with the minimum at 2 a. m. and 2 p. m., except that in summer the minimum occurs about one hour earlier. Generally the temperature maxima precede the pressure maxima by about two hours, implying that the semidiurnal pressure wave follows the temperature wave at an interval of two hours throughout the year. In winter the amplitudes have nearly the following relation,

$$-3^{\circ} \Delta T \propto +0.018 \Delta B, \text{ or } -1^{\circ} F \propto +0.0030 \text{ inch,}$$

while in summer the relation is follows,

$$-2^{\circ} \Delta T \propto +0.015 \Delta B, \text{ or } -1^{\circ} F \propto +0.0075 \text{ inch.}$$

Hence, the temperature wave in summer is two and one-half times as effective in producing the pressure wave as it is in the winter. In considering the dynamic relations of these waves, it is necessary to bear in mind that the entire system is moving from east to west in the atmosphere, or from right to left in the diagram, and the relative position in the semidiurnal, as in the diurnal waves, is that the temperature waves precede the pressure waves. If a physical process is concerned, as the vertical movement of convectional currents with expanding heads, or the downward flow of cool air along the sides of the warm diurnal cone, then this time-lag of two hours represents the interval connecting the temperature cause with the pressure effect. It is, however, quite clear that the diurnal pressure waves have their origin in a temperature wave, rather than in a forced dynamic wave as suggested by Lord Kelvin.

*Tridiurnal wave.*—We shall divide the year into two portions for discussing the tridiurnal wave: first, October to March, and, second, April to September. In the winter period it is seen that a fair agreement exists in the phases of the maxima of the temperature and the pressure waves, and that, with the system of coordinates here employed, they are in approxi-

mately direct synchronism. In the summer months, on the other hand, although the correspondence between the two sets of curves is much less satisfactory, there is suggested a synchronism of the inverse type, such that the phases of the temperature and pressure are opposite to one another. It will hardly be safe to lay down more definite conclusions regarding these tridiurnal curves, because we should not only require to have for discussion very perfect original curves in the atmosphere, but also it would be necessary to integrate throughout the entire range in altitude—that is, through the strata of the atmosphere affected by the diurnal disturbance—instead of limiting our summation to three selected curves.

A further discussion of these curves in connection with the vapor tension, the electric potential gradient, the coefficient of dissipation, and the phenomena of atmospheric electricity generally will be found in the next paper of this series, while their relations to the diurnal variation of the earth's magnetic field will be taken up in a still later paper.

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By H. H. KIMBALL, Librarian and Climatologist.

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- Science. New York. New Series. Vol. 21.*  
 Rotch, A. Lawrence. The St. Petersburg conference on the exploration of the atmosphere. Pp. 461-465.  
 Barus, Carl. Radiation associated with X-rays. Pp. 551-566.  
 Chester, C. M. The total solar eclipse of August 29-30, 1905. Pp. 635-637.  
*Scientific American. New York. Vol. 92.*  
 L. Some weather observations. P. 262.  
*Scientific American Supplement. New York. Vol. 59.*  
 Poynting, J. H. Radiation pressure. P. 24435.  
 — Rain: its cause. Pp. 24474-24475.  
 — The Piesmic barometer. P. 24482.  
 — The structure of the atom. P. 24498.  
*Nature. London. Vol. 71.*  
 Bryan, G. H. Progress in aerial navigation. Pp. 463-465.  
 — [Kite ascents made on the yacht of the Prince of Monaco in the Mediterranean and North Atlantic Ocean in the summer of 1904.] [Note on work of H. Hergesell.] P. 467.  
 — Effect of autumnal rainfall upon wheat crops. Pp. 470-471.  
 Rotch, A. Lawrence. Inversions of temperature and humidity in anticyclones. Pp. 510-511.  
*Geographical Journal. London. Vol. 25.*  
 Scott, Robert F. Results of the National Antarctic Expedition. [Climate.] Pp. 353-373.  
*Symons's Meteorological Magazine. London. Vol. 40.*  
 — The rainfall of the six months, September, 1904-February, 1905. Pp. 21-25.  
 Dansey, R. P. The glacial snow of Ben Nevis. Pp. 29-32.  
 Harvey, C. Wigan. A quarter of a century's rainfall at Throcking, Herts. P. 32.  
 Burt, Theodore. Meteorological observations in Pemba during 1903 and 1904. Pp. 34-35.  
*Knowledge. London. New Series. Vol. 2.*  
 Ingram, Beresford. "Ad Infinitum." The structure of the atom. Pp. 74-75.  
 MacDowall, Alex. B. Forecasting seasons. P. 80.  
*Science Abstracts. London. Vol. 8.*  
 Ros[enhain], W. Manufacture of thermometer glass at Jena. [Abstract of report of E. Grieshammer.] P. 162.  
 B[aynes], R. E. Formula for gaseous diffusion. [Abstract of article of P. Langevin.] P. 163.  
 Ros[enhain], W. Thermometer glass and the annealing thermometers. [Abstract of article of G. Müller.] P. 176.  
*Scottish Geographical Magazine. Edinburgh. Vol. 21.*  
 Brown, Rudmose. Argentine Antarctic station. Pp. 207-210.  
*Journal of Geography. New York. Vol. 4.*  
 Kirchwey, Clara B. Laboratory work in physical geography in secondary schools. [Atmosphere.] Pp. 122-130.